Enhancing the seismic resilience of residential buildings in Aotearoa NZ through the reuse of waste tyres

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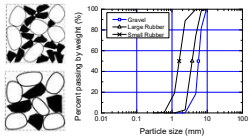
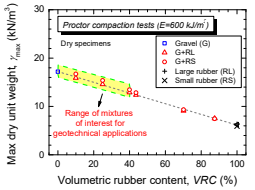
GERS – Geotechnical Engineering for Resilience and Sustainability

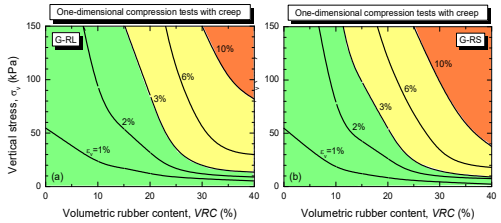
E/S/R Science for Communities

Geotechnical Properties of Gravel-Rubber Mixtures (GRMs)





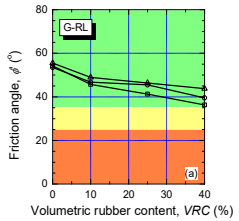
Dry Unit Weigh (γ_d): If *VRC* ↗ **then** γ_d ↘



Vertical Strain: If *VRC* ↗ **then** vertical strain ↗

- Use of smaller rubber particles induces larger vertical strain under the same stress and *VRC* conditions.

GRMs with VRC ≤ 40% are light-weight materials that meet strength and compressibility performance-based design criteria as bearing fills for foundation engineering applications.



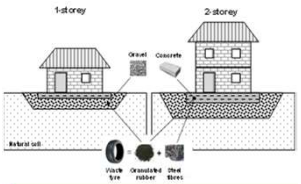
- **If** *VRC* ↗ **then** φ ↘
- **If** confining pressure ↗ **then** φ ↘

Background & Objectives

- New Zealand produces over **5 million end-of life tyres (ELTs)** per year and disregards 70% of these in landfills, stockpiles or illegally.
- **Recycling** and **reuse** of ELTs in civil engineering applications is an effective way to minimise environmental and health issues associated with such waste materials and concurrently reduce high demand of natural aggregates.
- **A multi-disciplinary geo-structural-environmental engineering project** funded by **MBIE**
- Jointly by the University of Canterbury and the Institute of Environmental Science and Research Ltd. (ESR)
- Evaluate the reuse of ELTs in foundation engineering applications.

Examples of illegal ELT disposal (photos courtesy of Waikato Regional Council)

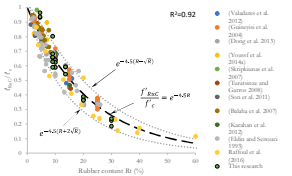
This project aims at developing the *eco-rubber geotechnical seismic isolation (ERGSI) foundation system* for improving the seismic performance of NZ medium-density low-rise buildings reusing ELTs.



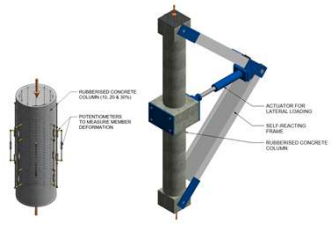
Rubberised concrete

- Investigation is underway on the development of practical rubberised concrete mixes of varying rubber contents.
- The rubber contents: 10% to 30% aggregate replacement (by volume). The mixes have been developed in such a way as to (follow as closely as possible) batching processes in industry, minimisation of the use of cement by including supplementary cementitious materials (e.g. fly ash and silica fume).
- Rubberised concrete will be assessed through large-scale tests, i.e. four point bending tests of beams (flexural response), concentric axial load tests of reinforced columns (stress-strain relationships) and cyclic lateral loading of axially loaded columns.
- Free vibration testing: Effect of ELTs on damping within the elastic range of the member. Studies in literature indicate an increase in damping.

Material testing: a) Compression and modulus of elasticity tests, b) Splitting-tensile test, c) Flexural strength test

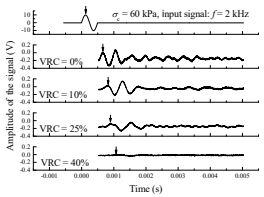


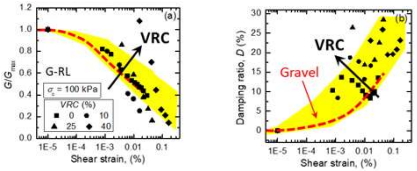
Compressive strength reduction versus rubber content



Compression test and cyclic loading test simulating beam-column members

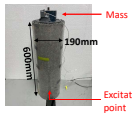
ERGSI Seismic Performance



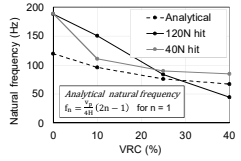


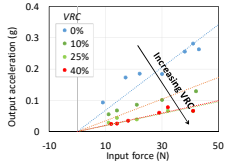
- **If** *VRC* ↗ **&** confining pressure ↗ **then** shear stiffness ↘
- **If** *VRC* ↗ **then** damping ratio ↗

Impact Hammer and Accelerometers

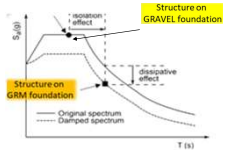


Specimen Set-Up.





- **If** *VRC* ↗ **then** natural frequency ↘ (seismic base isolation capacity)
- **If** *VRC* ↗ **then** output acceleration ↘ (seismic dissipative effect)



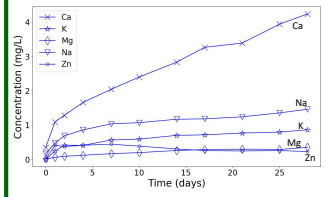
ERGSI foundation systems have excellent dissipative and seismic base isolation properties. Impact tests show that GRMs with VRC = 40% would reduce the seismic acceleration at foundation level by 3.5 times and significantly increase the natural period of the system.

Leaching properties of GRMs

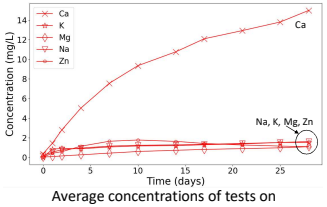
- Six batch tests were conducted for 28 days
- Samples were taken on days 0, 1, 2, 4, 7, 10, 14, 17, 21, 25, and 28 to track leaching characteristics.
- Ca, Na and K contents are attributed to the gravel and the Zn and Mg to the tyres.
- Smaller rubber chip size has an increasing effect on **leachate concentrations**.

Test	Volumetric rubber content (VRC) (%)	Rubber chip size	Gravel shape
1	40	Large	Rounded
2	40	Large	Rounded
3	40	Large	Rounded
4	40	Small	Rounded
5	40	Small	Rounded
6	40	Small	Rounded

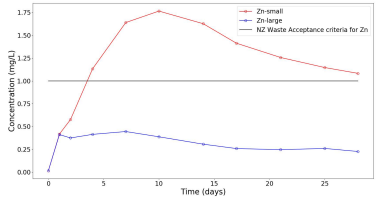
The use of GRMs with large rubber size is environmentally acceptable. On the other hand, the use GRMs with small rubber size requires pre-treatment or containment of GRMs before implementation since Zn concentration exceeds WAC for class B landfills.



Average concentrations of tests on **large** tyre chip mixes



Average concentrations of tests on **small** tyre chip mixes



Concluding remarks

- ELTs are posing environmental problems in New Zealand.
- They are a great source of environmentally friendly and sustainable building materials.
- They may provide novel and effective engineering solutions to attain structures with enhanced seismic resilience.
- Ideal materials for developing affordable, medium-density, low-rise buildings (high demand in New Zealand).
- Therefore, The reuse of ELTs mixed with gravel and concrete to develop **ERGSI foundation systems** is an innovative, promising, and cost-effective solution to significantly improve the seismic performance of buildings and structures with energy dissipation. This system composed of (a) a shallow and resilient layer of mixed shredded tyres and gravel, and (b) a flexible rubber–concrete raft foundation.

Acknowledgments

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References

- Hernandez, E., Palermo, A., Granello., G, Chiaro, G. & Banasiak, L. (2020). Eco-rubber seismic-isolation foundation system, a sustainable solution for the New Zealand context. *Structural Engineering International*, 30(2); 192-200, DOI: 10.1080/10168664.2019.1702487.
- Chiaro G., Tasalloti A., Banasiak L., Palermo A., Granello G. & Rees S. (2020). Sustainable recycling of end-of-life tyres in civil (geotechnical) engineering applications: turning issues into opportunities in the New Zealand context. NZ Geomechanics News, 99: 38-47.
- Tasalloti A., Chiaro G., Banasaik L. & Palermo A. (2021). Experimental investigation of the mechanical behaviour of gravel-granulated tyre rubber mixtures. *Construction and Building Materials*, pp. 14 (in press).
- Tasalloti A., Chiaro G., Palermo A. & Banasiak L.J. (2020). Effect of rubber crumbs volumetric content on the shear strength of gravelly soil in direct shear apparatus. Proc. of Geo-Congress 2020, 25-28 Feb., Minneapolis, Minnesota, USA [ASCE Geotechnical Special Publication, 319: 259-266].
- Banasiak L.J., Chiaro G., Palermo A. & Granello G. (2021). Environmental implications of the recycling of end-of-life tires in seismic-isolation foundation systems. Proc. of 1st Int. Symp. on Construction Resources for Environmentally Sustainable Technologies, March 10-12, Fukuoka, Japan, pp. 10 (in press).